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Carralero et al.

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(54) **METHOD AND APPARATUS FOR MANAGING THE DISTRIBUTION OF ELECTRICAL ENERGY IN A POWER DISTRIBUTION GRID**

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H02J 3/14 (2006.01)

(52) **U.S. Cl.**
CPC ***H02J 3/14*** (2013.01); *Y02B 70/3225* (2013.01); *Y04S 20/222* (2013.01); *Y10T 307/724* (2015.04)

(58) **Field of Classification Search**
USPC 307/85
See application file for complete search history.

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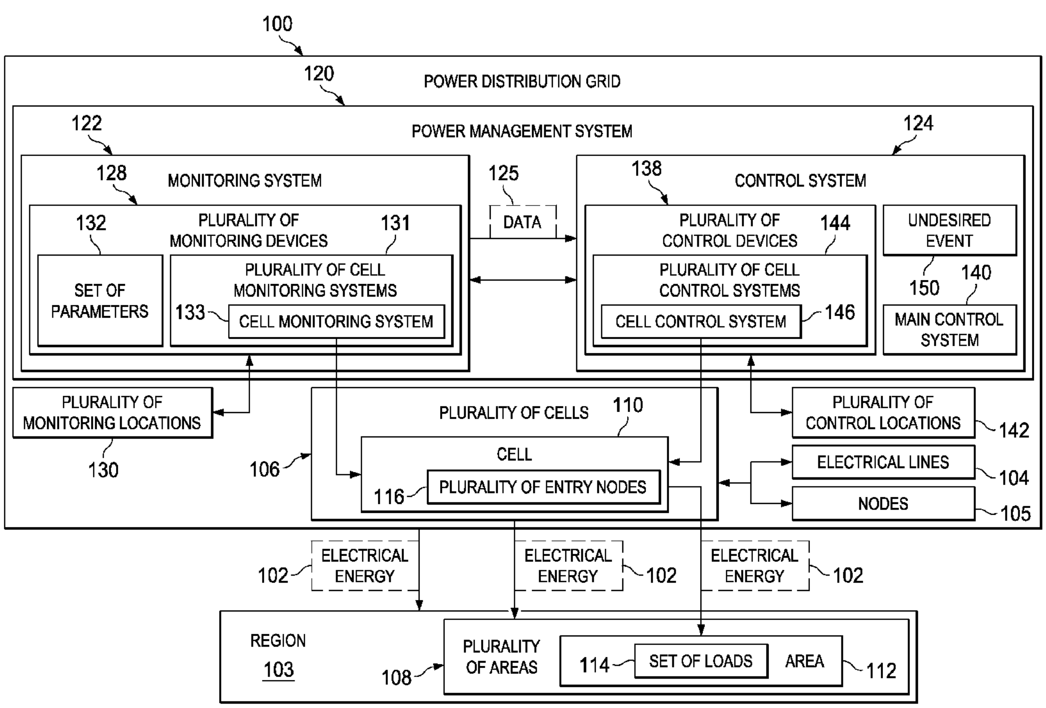
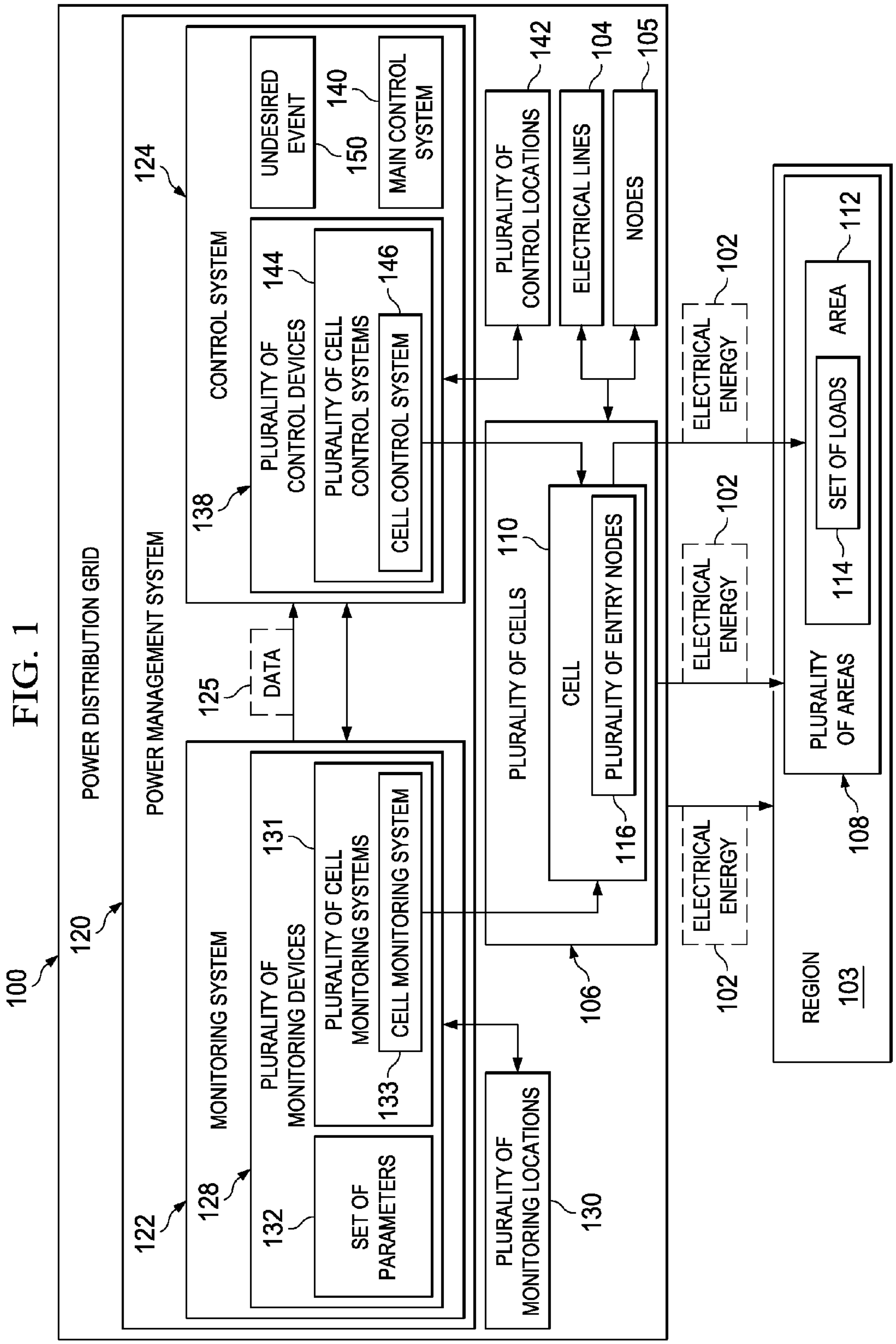
(57) **ABSTRACT**

A power distribution grid comprising a plurality of cells configured to be electrically connected to each other and a power management system. A cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell. The cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell. The power management system is configured to manage a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells.

20 Claims, 7 Drawing Sheets





100
120
POWER DISTRIBUTION GRID
POWER MANAGEMENT SYSTEM
122
MONITORING SYSTEM
128
PLURALITY OF MONITORING DEVICES
132
SET OF PARAMETERS
131
PLURALITY OF CELL MONITORING SYSTEMS
133
CELL MONITORING SYSTEM
125
DATA
124
CONTROL SYSTEM
138
PLURALITY OF CONTROL DEVICES
144
PLURALITY OF CELL CONTROL SYSTEMS
146
CELL CONTROL SYSTEM
UNDESIRED EVENT
150
140
MAIN CONTROL SYSTEM
PLURALITY OF MONITORING LOCATIONS
130
PLURALITY OF CONTROL LOCATIONS
142
ELECTRICAL LINES
104
NODES
105
106
PLURALITY OF CELLS
110
CELL
PLURALITY OF ENTRY NODES
116
ELECTRICAL ENERGY
102
REGION
103
108
PLURALITY OF AREAS
112
AREA
SET OF LOADS
114

FIG. 1

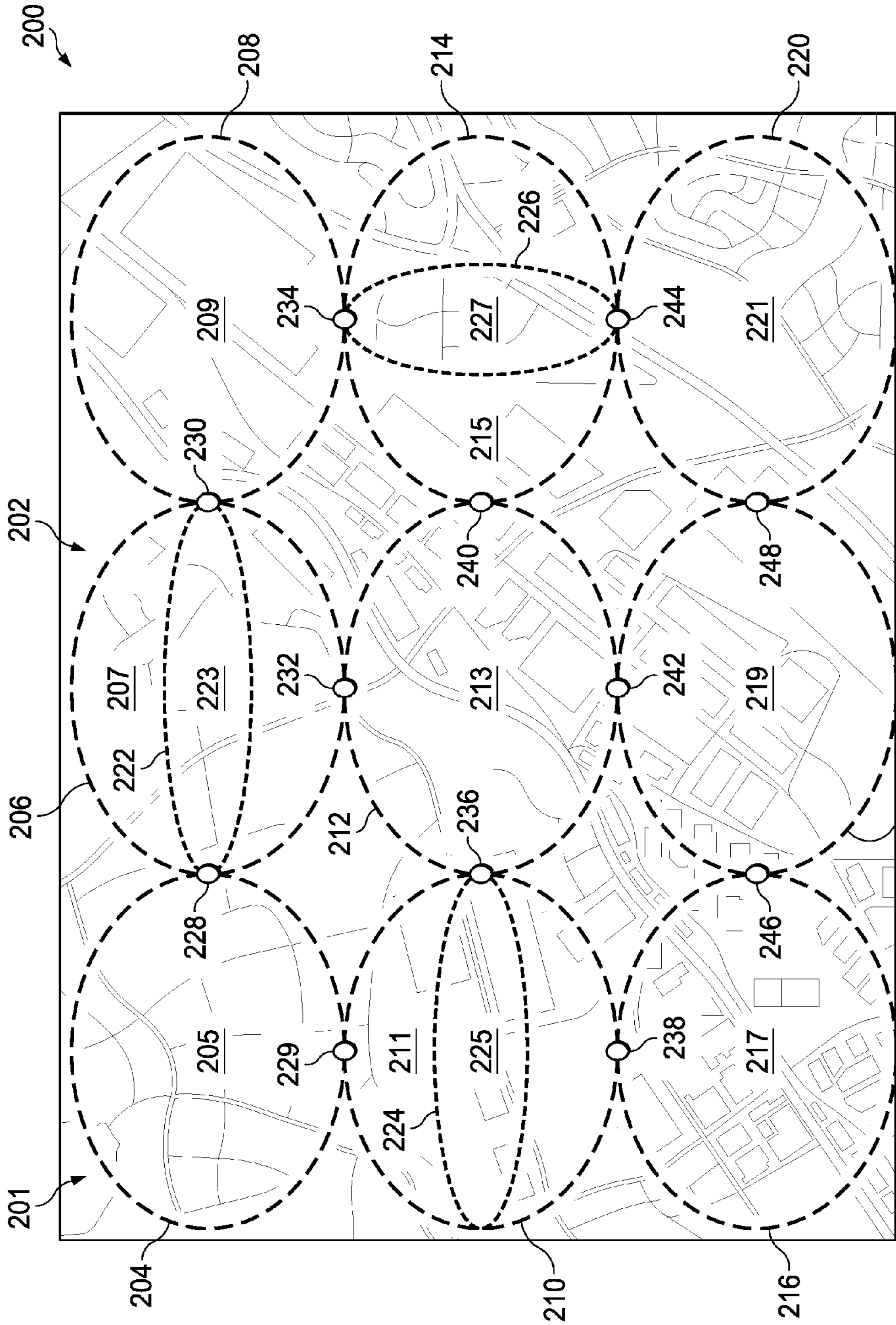

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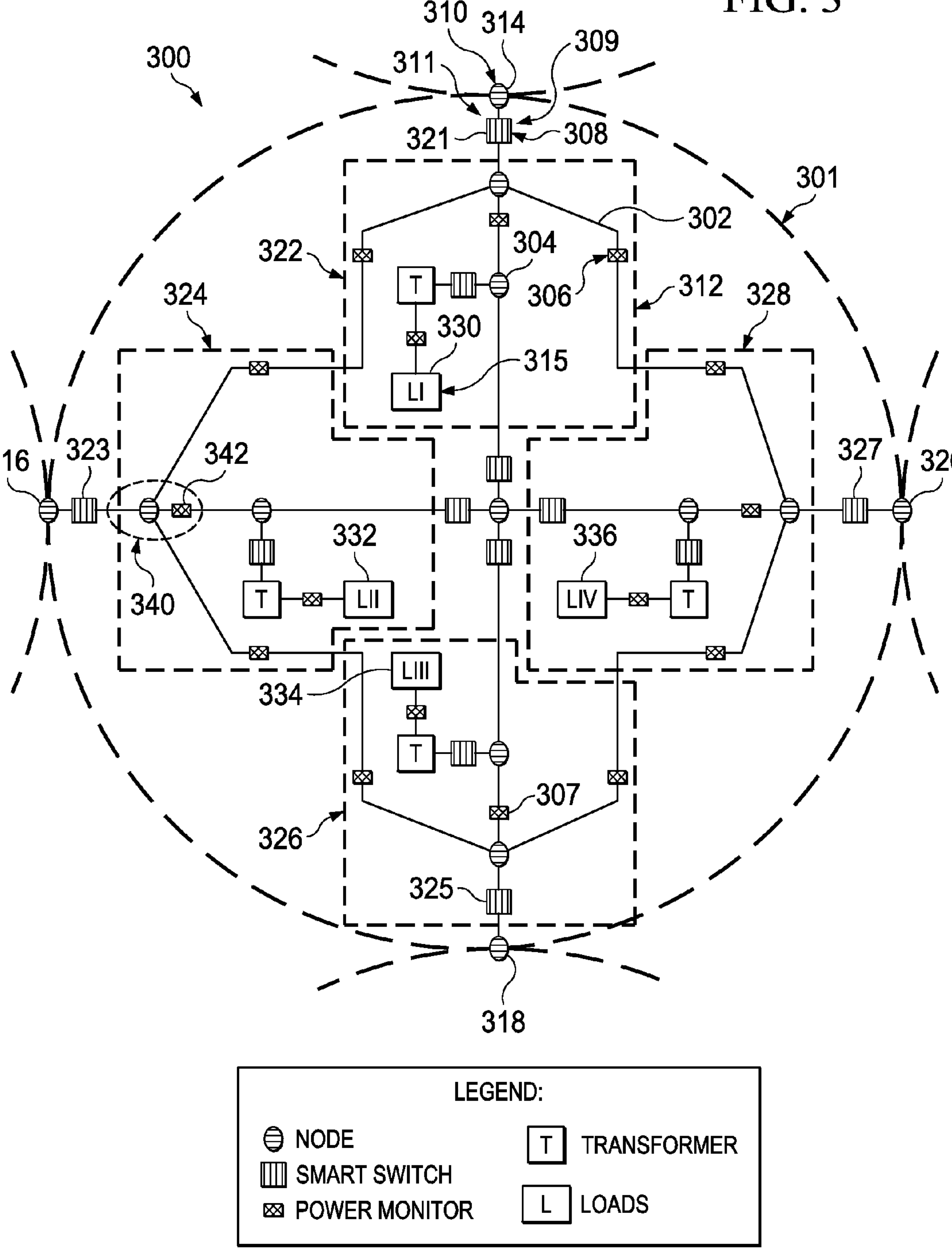
FIG. 2

FIG. 3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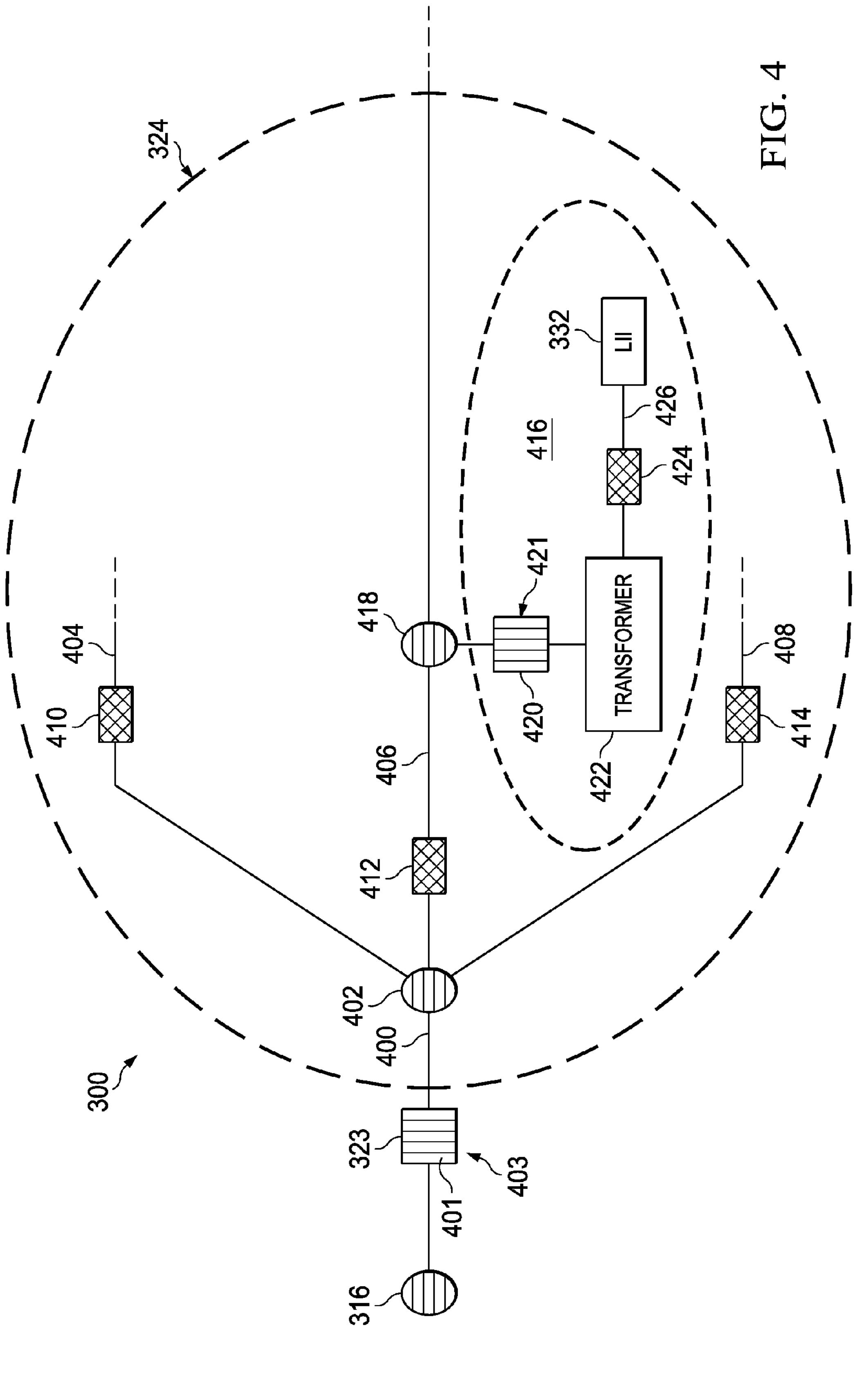
328
330
332
334
336
340
342
T
LI
LII
LIII
LIV
LEGEND:
NODE
SMART SWITCH
POWER MONITOR
T TRANSFORMER
L LOADS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316
323
401
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400
402
412
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410
404
418
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421
422
TRANSFORMER
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424
426
LII
332
414
408

FIG. 4

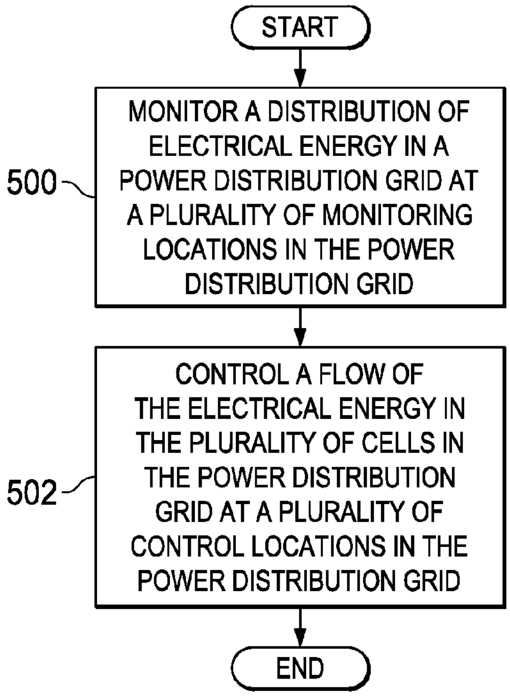

START
MONITOR A DISTRIBUTION OF ELECTRICAL ENERGY IN A POWER DISTRIBUTION GRID AT A PLURALITY OF MONITORING LOCATIONS IN THE POWER DISTRIBUTION GRID
500
CONTROL A FLOW OF THE ELECTRICAL ENERGY IN THE PLURALITY OF CELLS IN THE POWER DISTRIBUTION GRID AT A PLURALITY OF CONTROL LOCATIONS IN THE POWER DISTRIBUTION GRID
502
END

FIG. 5

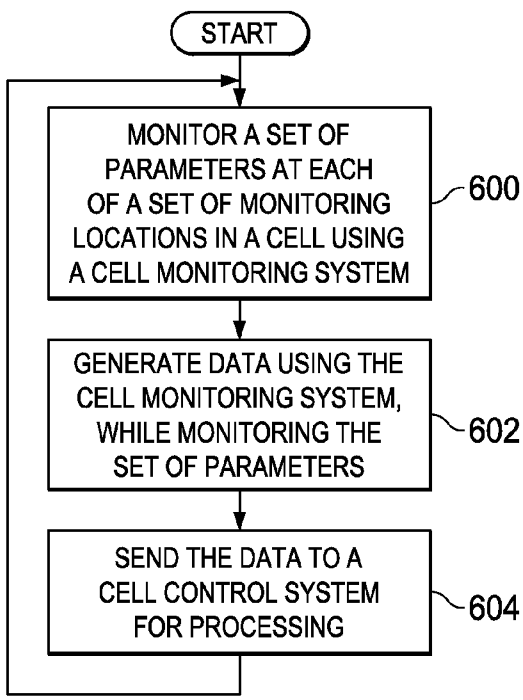

START
MONITOR A SET OF PARAMETERS AT EACH OF A SET OF MONITORING LOCATIONS IN A CELL USING A CELL MONITORING SYSTEM
600
GENERATE DATA USING THE CELL MONITORING SYSTEM, WHILE MONITORING THE SET OF PARAMETERS
602
SEND THE DATA TO A CELL CONTROL SYSTEM FOR PROCESSING
604

FIG. 6

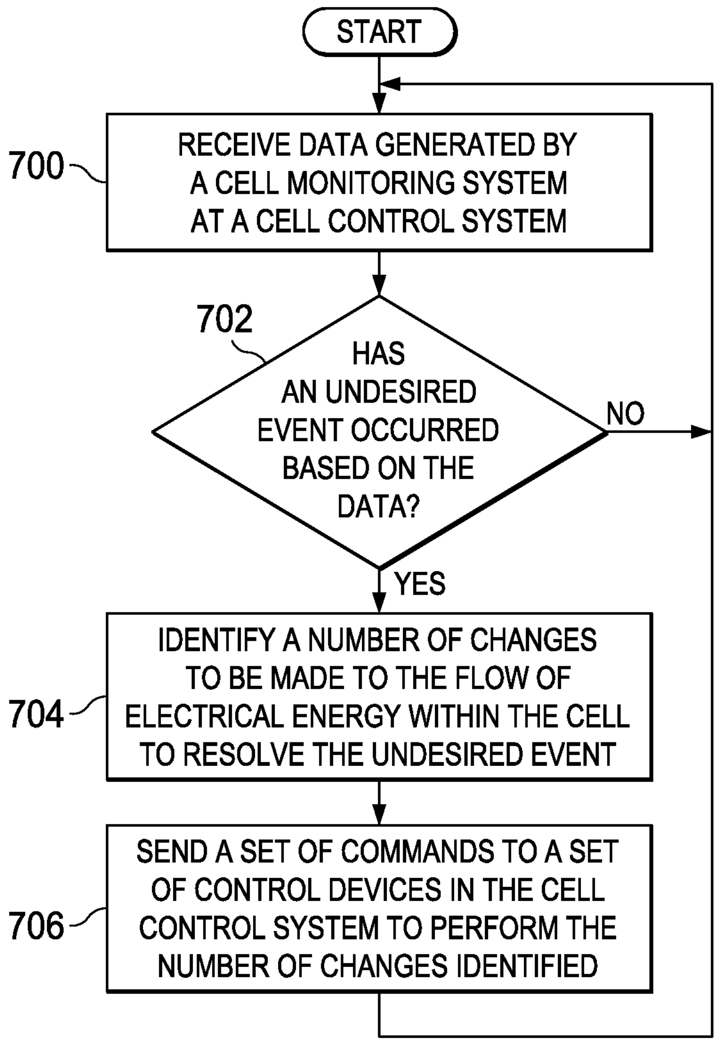
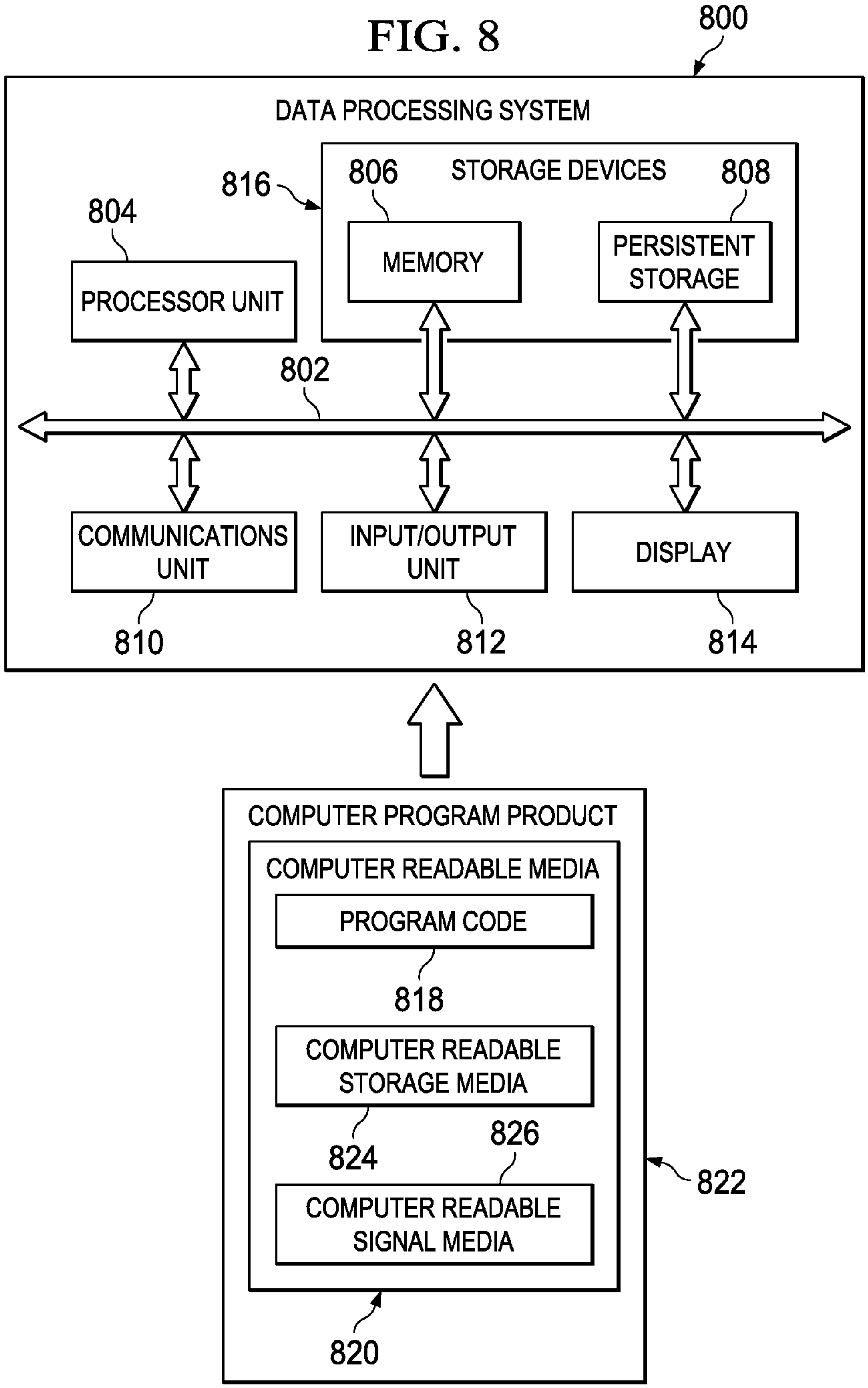

START
700
RECEIVE DATA GENERATED BY A CELL MONITORING SYSTEM AT A CELL CONTROL SYSTEM
702
HAS AN UNDESIRED EVENT OCCURRED BASED ON THE DATA?
NO
YES
704
IDENTIFY A NUMBER OF CHANGES TO BE MADE TO THE FLOW OF ELECTRICAL ENERGY WITHIN THE CELL TO RESOLVE THE UNDESIRED EVENT
706
SEND A SET OF COMMANDS TO A SET OF CONTROL DEVICES IN THE CELL CONTROL SYSTEM TO PERFORM THE NUMBER OF CHANGES IDENTIFIED

FIG. 7

FIG. 8


800
DATA PROCESSING SYSTEM
816
806
STORAGE DEVICES
808
804
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
802
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
810
812
814
COMPUTER PROGRAM PRODUCT
COMPUTER READABLE MEDIA
PROGRAM CODE
818
COMPUTER READABLE STORAGE MEDIA
824
826
822
COMPUTER READABLE SIGNAL MEDIA
820

METHOD AND APPARATUS FOR MANAGING THE DISTRIBUTION OF ELECTRICAL ENERGY IN A POWER DISTRIBUTION GRID

BACKGROUND INFORMATION

1. Field

The present disclosure relates generally to a power distribution grid and, in particular, to a method and apparatus for monitoring and controlling the distribution of electrical energy to a plurality of areas in a region using a plurality of cells in the power distribution grid.

2. Background

A power distribution grid may include any number of power lines, transformers, substations, wires, and/or other suitable components configured to deliver electrical energy to one or more loads electrically connected to the power distribution grid. This electrical energy is supplied to the power distribution grid by a power transmission grid. The power transmission grid is configured to transfer electrical energy generated by a power generation system to the power distribution grid.

The power generation system may take a number of different forms. For example, the power generation system may be a power plant, a power generation station, a microgrid, or some other suitable type of power generation system. The electrical energy generated by the power generation system may be generated using, for example, without limitation, mechanical, chemical, thermal, solar, wind, fusion, fission, geothermal, hydroelectric, and/or other suitable types of energy. A power generation system, a power transmission grid, and a power distribution grid may together form a power delivery system. Different portions of a power delivery system may be utilized and operated by different power utilities and consumers.

In some situations, an undesired event may occur within a power distribution grid. An undesired event within a power distribution grid may take the form of, for example, without limitation, a power outage, a short circuit, an inconsistency in one or more components in the power distribution grid, a deviation from a desired quality and/or desired stability for the distribution of electrical energy that is outside of selected tolerances, or some other suitable type of undesired event. In some cases, an undesired event may be referred to as a "fault".

Currently available systems for resolving undesired events that occur within a power distribution grid may require more time, effort, personnel, and/or resources than desired. For example, without limitation, some currently available systems for resolving undesired events that occur within a power distribution grid include dispatching a maintenance crew to the area in which the undesired event has occurred. The maintenance crew may then identify and resolve this undesired event. However, this process may take more time and effort than desired.

For example, when the undesired event is a power outage in a particular area, identifying and locating the cause of the power outage within the particular area may require more time and effort than desired with some currently available systems for managing a power distribution grid. Further, the particular area may experience a loss of power for a longer period of time than desired while the maintenance crew works to identify and locate the cause of the power outage. Therefore, it would be desirable to have a method and apparatus that takes into account at least some of the issues discussed above as well as possibly other issues.

SUMMARY

In one illustrative embodiment, a power distribution grid comprises a plurality of cells configured to be electrically connected to each other and a power management system. A cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell. The cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell. The power management system is configured to manage a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells.

In another illustrative embodiment, a power distribution grid comprises a plurality of cells configured to be electrically connected to each other, a monitoring system, and a control system. A cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell. The cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell. The cell comprises a plurality of sectors configured to be electrically connected to each other. A sector in the plurality of sectors is configured to deliver the electrical energy to a load electrically connected to the sector. The sector is configured to have a capability to receive the electrical energy from more than one entry node in the plurality of entry nodes. The monitoring system is configured to monitor a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells. The control system is configured to control the distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to the other areas by the other cells in the plurality of cells.

In yet another illustrative embodiment, a method for managing a power distribution grid is provided. A distribution of electrical energy in the power distribution grid is monitored at a plurality of monitoring locations. The power distribution grid comprises a plurality of cells configured to distribute the electrical energy to a plurality of areas. A cell in the plurality of cells has a plurality of entry nodes configured to allow the electrical energy to flow into the cell. A flow of the electrical energy in the plurality of cells is controlled in the power distribution grid at a plurality of control locations. The flow of the electrical energy in the cell in the plurality of cells is controlled independently of the flow of the electrical energy in other cells in the plurality of cells.

The features, functions, and benefits can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives, and features thereof will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an illustration of a power distribution grid in the form of a block diagram in accordance with an illustrative embodiment;

FIG. **2** is an illustration of a power distribution grid in accordance with an illustrative embodiment;

FIG. **3** is an illustration of a cell in accordance with an illustrative embodiment;

FIG. **4** is an illustration of a sector in a cell in accordance with an illustrative embodiment;

FIG. **5** is an illustration of a process for managing a distribution of electrical energy by a power distribution grid in the form of a flowchart in accordance with an illustrative embodiment;

FIG. **6** is an illustration of a process for monitoring the distribution of electrical energy by a cell in a power distribution grid in the form of a flowchart in accordance with an illustrative embodiment;

FIG. **7** is an illustration of a process for controlling a flow of electrical energy in a cell in a power distribution grid in the form of a flowchart in accordance with an illustrative embodiment; and

FIG. **8** is an illustration of a data processing system in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

The different illustrative embodiments recognize and take into account different considerations. For example, the different illustrative embodiments recognize and take into account that some currently used configurations for power distribution grids may be unable to begin resolving an undesired event and restore power to an area in which the undesired event has occurred as quickly as desired. The undesired event may be, for example, a power outage.

Further, the different illustrative embodiments recognize and take into account that it may be desirable to have a configuration for a power distribution grid that allows a location in which an undesired event has occurred to be isolated for maintenance while allowing power to be restored to areas around this location. In particular, it may be desirable to have a power distribution grid that is capable of minimizing the area affected by an undesired event.

Thus, the different illustrative embodiments provide a method and apparatus for managing a power distribution grid. In one illustrative embodiment, a power distribution grid comprises a plurality of cells configured to be electrically connected to each other and a power management system. A cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell. The cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell. The power management system is configured to manage a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells.

With reference now to the figures and, in particular, with reference to FIG. **1**, an illustration of a power distribution grid in the form of a block diagram is depicted in accordance with an illustrative embodiment. Power distribution grid **100** is an example of one manner in which the different illustrative embodiments may be implemented. In some illustrative examples, power distribution grid **100** may be referred to as a power distribution network.

Power distribution grid **100** is configured to distribute electrical energy **102** to region **103**. Region **103** may be, for example, without limitation, a geographical region, a city, an area in a city, a town, a neighborhood, or some other suitable type of region.

As used herein, "electrical energy", such as electrical energy **102**, is potential energy that results from conservative Coulomb forces. Electrical energy **102** may be measured in, for example, joules (J). The rate at which electrical energy **102** is transferred is referred to as "power", "electrical power", or "electric power". Power may be measured in watts (W). One watt is measured as one joule per second.

Electrical energy **102** may comprise energy generated using, for example, without limitation, at least one of mechanical, chemical, thermal, solar, wind, fusion, fission, geothermal, hydroelectric, and other suitable types of energy. The phrase "at least one of", as used herein, when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, "at least one of item A, item B, and item C" may include, without limitation, item A or item A and item B. This example also may include item A, item B, and item C, or item B and item C.

Power distribution grid **100** comprises electrical lines **104** and nodes **105**. As used herein, an "electrical line" may be any wire, cable, or other suitable type of conduit configured to carry electrical energy **102**. In these illustrative examples, an electrical line may also be referred to as a power line, a distribution line, or a power distribution line. Electrical lines **104** may be two or more electrical lines. For example, electrical lines **104** may include two, three, 10, 20, 50, 100, or some other suitable number of electrical lines.

Further, a "node", as used herein, is a connection between two or more electrical lines. This connection may take various forms. For example, without limitation, the connection between two or more electrical lines may comprise at least one of an intersection of two or more electrical lines, a hub, a bus, a busbar, an electrical circuit, a substation, an electrical line connecting two or more electrical lines, or some other suitable type of connection between two or more electrical lines.

Electrical lines **104** and nodes **105** may be configured to form plurality of cells **106** in power distribution grid **100**. As used herein, a "plurality of" items means one or more items. For example, plurality of cells **106** means two or more cells.

In these illustrative examples, electrical lines **104** and nodes **105** may be organized into plurality of cells **106** to distribute electrical energy **102** to plurality of areas **108** in region **103**. In particular, each cell in plurality of cells **106** is configured to distribute electrical energy **102** to a corresponding area in plurality of areas **108** in region **103**. Plurality of areas **108** may be distinct areas that do not overlap within region **103** in these illustrative examples. However, in other illustrative examples, one or more areas in plurality of areas **108** may overlap.

Cell **110** is an example of one of plurality of cells **106**. Cell **110** is configured to distribute electrical energy **102** to area **112** in plurality of areas **108**. More specifically, cell **110** is configured to deliver electrical energy **102** to set of loads **114** in area **112** that are electrically connected to cell **110**.

As used herein, a "set of" items means one or more items. For example, set of loads **114** means one or more loads. Further, as used herein, a "load", such as one of set of loads **114**, may be any circuit, system, or device configured to consume electrical energy **102**. A load may take various forms. For example, without limitation, a load may be selected from cumulative loads from a manufacturing facility, a building, a home, or one of an appliance, a computer, a car, an electrical device, an electromechanical device, a computer system, or some other suitable type of load.

Further, as used herein, when a first component, such as a load in set of loads **114**, is electrically connected to a second component, such as cell **110**, the first component is connected to the second component such that electric current can be sent from the first component to the second component, the second component to the first component, or a combination of the two. In other words, the first component and the second component are connected such that electrical energy **102** may flow between the two components. For example, when a load is electrically connected to cell **110**, electrical energy **102** may be transferred from cell **110** to the load.

In some cases, the first component may be electrically connected to the second component without any additional components between the two components. In other illustrative examples, the first component may be electrically connected to the second component by one or more other components.

As depicted, cell **110** has plurality of entry nodes **116**. An "entry node", as used herein, is a node through which electrical energy **102** flows into a cell. In one illustrative example, cell **110** may have four entry nodes through which electrical energy **102** can flow into cell **110**.

One or more of plurality of entry nodes **116** may be used to electrically connect cell **110** to other cells in plurality of cells **106**. For example, an entry node in plurality of entry nodes **116** for cell **110** may be used to electrically connect cell **110** to at least one other cell in plurality of cells **106**. In these illustrative examples, two cells that are electrically connected to each other by a node may be considered to share that node.

As depicted, power distribution grid **100** also includes power management system **120**. Power management system **120** is configured to manage the distribution of electrical energy **102** to region **103** by power distribution grid **100**. In these illustrative examples, power management system **120** comprises monitoring system **122** and control system **124**.

Monitoring system **122** is configured to monitor plurality of cells **106** in power distribution grid **100**. In particular, monitoring system **122** monitors the distribution of electrical energy **102** to plurality of areas **108** in region **103** by plurality of cells **106**.

In these illustrative examples, monitoring system **122** comprises plurality of monitoring devices **128**. Plurality of monitoring devices **128** is configured to monitor plurality of monitoring locations **130** in power distribution grid **100**. As used herein, a "monitoring location" in power distribution grid **100** is a location along one of electrical lines **104** in power distribution grid **100** being monitored.

Plurality of monitoring devices **128** may form plurality of cell monitoring systems **131** for plurality of cells **106**. Each cell monitoring system in plurality of cell monitoring systems **131** is configured to monitor a corresponding cell in plurality of cells **106**. For example, cell monitoring system **133** in plurality of cell monitoring systems **131** is configured to monitor cell **110**. Cell monitoring system **133** may be configured to monitor cell **110** independently of other cells in plurality of cells **106**. In some cases, cell monitoring system **133** may be considered part of cell **110**.

Each monitoring device in plurality of monitoring devices **128** is configured to monitor set of parameters **132** at a corresponding location in plurality of monitoring locations **130**. More specifically, each monitoring device in plurality of monitoring devices **128** generates data **125** while monitoring set of parameters **132** at a corresponding location in plurality of monitoring locations **130**.

Set of parameters **132** may include, for example, parameters related to the distribution of electrical energy **102** at a particular location and/or other suitable parameters. In these illustrative examples, set of parameters **132** includes at least one of voltage, current, frequency, electrical power, electrical energy, temperature, impedance, capacity, thermal conductivity, and other suitable types of parameters.

A monitoring device in plurality of monitoring devices **128** may take various forms. For example, a monitoring device in plurality of monitoring devices **128** may comprise at least one of a voltmeter, an ammeter, an ohmmeter, a power meter, a temperature sensor, a processor unit, a communications unit, and any other suitable type of sensor, meter, or monitoring device capable of monitoring one or more of set of parameters **132**. In some cases, plurality of monitoring devices **128** may be configured to communicate with each other.

In these illustrative examples, plurality of monitoring devices **128** is configured to monitor set of parameters **132** at plurality of monitoring locations **130** continuously. Each monitoring device in plurality of monitoring devices **128** generates data **125** while monitoring a particular location in plurality of monitoring locations **130**. Data **125** may include, for example, without limitation, values for set of parameters **132**.

In some illustrative examples, data **125** also may include information derived from values for set of parameters **132**. For example, data **125** may include information about the health and/or status of power distribution grid **100** with respect to the particular location. In other illustrative examples, data **125** may include at least one of a report, a log, a spreadsheet, a table, an alert, and other suitable types of data identified by the monitoring device from monitoring set of parameters **132** at the particular location.

A monitoring device in plurality of monitoring devices **128** may generate data **125** continuously over time, periodically, and/or in response to some event. The event may be, for example, receiving a command, receiving a request for data **125**, receiving operator input, the lapse of a timer, or some other suitable type of event.

When plurality of monitoring devices **128** monitor plurality of monitoring locations **130** continuously, plurality of monitoring devices **128** may generate data **125** for plurality of monitoring locations **130** in substantially real-time. Generating data **125** in substantially real-time means generating data **125** at the fastest possible speeds without intentional and/or perceivable delays.

In some illustrative examples, data **125** generated by one monitoring device in plurality of monitoring devices **128** may be different from data **125** generated by another monitoring device in plurality of monitoring devices **128**. Further, in other illustrative examples, data **125** may be generated continuously by one monitoring device in plurality of monitoring devices **128**, while data **125** may be generated periodically by a monitoring device in plurality of monitoring devices **128**.

In these illustrative examples, the different monitoring devices in plurality of monitoring devices **128** are configured to send data **125** to control system **124** for processing. Plurality of monitoring devices **128** may send data **125** to control system **124** using a communications network.

This communications network may allow communications between plurality of monitoring devices **128** in monitoring system **122**, between plurality of control devices **138** in control system **124**, and between monitoring system **122** and control system **124**. Further, this communications network may be formed using a number of wireless communications links, a number of wired communications links, one or more of electrical lines **104**, a number of optical communications links, and/or other suitable types of communications links. Any configuration for a number of electrical lines **104** in power distribution grid **100** may be used in the communications network.

Control system **124** is configured to control the distribution of electrical energy **102** to region **103** by power distribution grid **100** using data **125** provided by monitoring system **122**. In particular, control system **124** controls the flow of electrical energy **102** through electrical lines **104** and nodes **105** in power distribution grid **100**.

Further, in controlling the distribution of electrical energy **102** to region **103**, control system **124** may be configured to substantially maintain desired power quality and desired power stability with respect to electrical energy **102** delivered to loads in region **103**. Still further, control system **124** may substantially maintain synchronization and communication between cells in plurality of cells **106** in power distribution grid **100**.

Additionally, control system **124** is configured to control each cell in plurality of cells **106** independently of other cells in plurality of cells **106**. For example, control system **124** controls the flow of electrical energy **102** within cell **110** independently of the flow of electrical energy **102** within other cells in plurality of cells **106**. In this manner, control system **124** may control the distribution of electrical energy **102** to area **112** by cell **110** independently of the distribution of electrical energy **102** to other areas in plurality of areas **108** by other cells in plurality of cells **106**.

In these illustrative examples, control system **124** comprises plurality of control devices **138** and main control system **140**. Each control device in plurality of control devices **138** is electrically connected to a corresponding electrical line in electrical lines **104** for power distribution grid **100**. Plurality of control devices **138** is configured to control the flow of electrical energy **102** through electrical lines **104** in power distribution grid **100** at plurality of control locations **142**.

As used herein, a "control location" is a location along one of electrical lines **104** in power distribution grid **100** at which the flow of electrical energy **102** through the electrical line may be changed. In some cases, a control location in plurality of control locations **142** may be located at substantially the same location as or near to a monitoring location in plurality of monitoring locations **130**.

A control device in plurality of control devices **138** may take various forms. For example, a control device in plurality of control devices **138** may comprise at least one of a switch, a switchgear, a flexible alternating current transmissions (FACTs) device, a fuse, a circuit breaker, a smart switch, a protective relay, an electronic filter, a phase shifter, a transformer, an adapter, a sensor, a processor unit, a communications unit, and some other suitable type of component.

A control device in plurality of control devices **138** that is electrically connected to one of electrical lines **104** at a particular location may change the flow of electrical energy **102** at this particular location in a number of different ways. For example, the control device may reduce the amount of electrical energy **102** that can flow through the electrical line at the location, decrease the impedance of the electrical line at the location, increase the impedance of the electrical line at the location, prevent the flow of electrical energy **102** through the electrical line at the location, and/or change the flow of electrical energy **102** though the electrical line at the location in some other suitable manner.

Plurality of control devices **138** may form plurality of cell control systems **144** for plurality of cells **106**. Each cell control system in plurality of cell control systems **144** is configured to control a corresponding cell in plurality of cells **106**. For example, cell control system **146** in plurality of cell control systems **144** is configured to control cell **110**. In some cases, cell control system **146** may be considered part of cell **110**.

Cell control system **146** is configured to control the flow of electrical energy **102** through cell **110** independently of the other cells in plurality of cells **106**. In particular, cell control system **146** may control the flow of electrical energy **102** through cell **110** using data **125** generated by, for example, cell monitoring system **133**.

In these illustrative examples, the portion of plurality of control devices **138** within cell control system **146** may be configured to communicate with each other and with the monitoring devices in cell monitoring system **133** for cell **110**. In this manner, cell monitoring system **133** and cell control system **146** may work together to control cell **110**. More specifically, cell **110** may use cell monitoring system **133** and cell control system **146** to control cell **110** autonomously. Autonomous control of cell **110** may be control of cell **110** by cell **110** without requiring additional information and/or input from other sources.

Further, in these illustrative examples, main control system **140** may be configured to control operation of at least a portion of plurality of cell monitoring systems **131** and/or at least a portion of plurality of cell control systems **144**. In particular, main control system **140** may be in communication with at least a portion of plurality of monitoring devices **128** and/or at least a portion of plurality of control devices **138**.

In some illustrative examples, main control system **140** may control the overall distribution of electrical energy **102** to region **103**. For example, main control system **140** may use at least a portion of plurality of control devices **138** to control the flow of electrical energy **102** within each of plurality of cells **106**.

Further, main control system **140** may use data **125** generated by plurality of monitoring devices **128** and/or other suitable information to control power distribution grid **100**. This other information may include, for example, without limitation, a power distribution policy, safety requirements, regulations, consumer requests, and/or other suitable types of information.

In these illustrative examples, the flow of electrical energy **102** in a cell, such as cell **110**, may be controlled in a number of different ways. For example, main control system **140** and/or cell control system **146** in control system **124** may control which entry nodes in plurality of entry nodes **116** through which cell **110** is configured to receive electrical energy **102**. This control may be based on, for example, data **125** generated by cell monitoring system **133** and/or other suitable information.

Further, control system **124** may also control the flow of electrical energy **102** to set of loads **114** electrically connected to cell **110**. For example, control system **124** may use cell control system **146** to control a pathway for electrical energy **102** from one of plurality of entry nodes **116** for cell **110** to a particular load in set of loads **114** electrically connected to cell **110**. In this manner, plurality of control devices **138** may have the capability to resolve undesired events, react to deviations from nominal voltage and frequency patterns, and reroute the flow of electrical energy **102** through cell **110**. In some cases, resolving undesired events may also be referred to as clearing faults.

In these illustrative examples, control system **124** may use data **125** generated by plurality of monitoring devices **128** to detect the occurrence of undesired event **150**. Undesired event **150** may comprise, for example, at least one of an undesired change to the flow of electrical energy **102** in one or more electrical lines **104**, a power outage or loss of power in a portion of area **112**, a short circuit, an inconsistency in one or more components of a cell, a deviation from a desired power quality and/or desired power stability for the distribution of electrical energy **102** that is outside of selected tolerances, and some other type of undesired event. In some cases, undesired event **150** may be referred to as a "fault".

Undesired event **150** may be any event that affects the distribution of electrical energy **102** to an area in plurality of areas **108** in an undesired manner. As one illustrative example, undesired event **150** may be a power outage in a portion of area **112**. This power outage may cause a loss of power to one or more of set of loads **114** electrically connected to cell **110**.

Cell control system **146** may detect the occurrence of undesired event **150** using data **125** generated by cell monitoring system **133**. In response to detecting undesired event **150**, cell control system **146** may use data **125** to determine the portion of cell **110** in which the cause of undesired event **150** is located. Cell control system **146** may then change the flow of electrical energy **102** through cell **110** to compensate for undesired event **150**.

In particular, cell control system **146** may isolate the portion of cell **110** in which the cause of undesired event **150** is located. In other words, cell control system **146** may reduce the flow of electrical energy **102** to this portion of cell **110**. The flow of electrical energy **102** to this portion of cell **110** may be reduced to about zero. In other words, cell control system **146** may prevent the flow of electrical energy **102** to this portion of cell **110**. In this manner, an operator, a maintenance crew, an electrician, a robotic operator, or some other suitable type of operator may be able to investigate and/or resolve the cause of the power outage.

In some cases, isolating this portion of cell **110** may not result in the restoration of power to all of set of loads **114**. Consequently, cell control system **146** reroutes the flow of electrical energy **102** through the electrical lines and/or nodes in cell **110** such that power is restored to all of set of loads **114**. In some cases, this restoration of power to all of set of loads **114** and the isolation of the portion of cell **110** in which undesired event **150** occurred may occur simultaneously within selected tolerances.

In this manner, monitoring system **122** and control system **124** may be used to manage the flow of electrical energy **102** through plurality of cells **106**. Further, monitoring system **122** and control system **124** may be used to manage the flow of electrical energy **102** between cells in plurality of cells **106**. For example, monitoring system **122** and control system **124** may manage the flow of electrical energy **102** through entry nodes that electrically connect cells in plurality of cells **106**.

With monitoring system **122** continuously monitoring power distribution grid **100**, control system **124** may be able to isolate undesired events, minimize the portion of an area affected by the undesired event, and restore power to the area more quickly and efficiently as compared to currently available systems for managing a power distribution grid. In some cases, continuous monitoring of power distribution grid **100** may allow control system **124** to monitor power distribution grid **100** and resolve undesired events that may occur within power distribution grid **100** in substantially real-time.

The illustration of power distribution grid **100** in FIG. **1** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

For example, in some illustrative examples, monitoring system **122** and control system **124** may have shared components. As one illustrative example, cell monitoring system **133** and cell control system **146** may be part of the same device in some cases. Further, in some cases, power distribution grid **100** may include additional components in addition to and/or in place of the ones described above. For example, power distribution grid **100** may also include any number of protective relays, voltage and current transformers, circuit breakers, fuses, control stations, and/or other suitable types of components.

In other illustrative examples, a portion of each cell control system in plurality of cell control systems **144** for a corresponding cell in plurality of cells **106** may be located remote to the area in plurality of areas **108** corresponding to that cell. As one illustrative example, cell control system **146** may include a computer system located remote to area **112** and configured to control the control devices in cell control system **146** remotely. For example, the control devices in cell control system **146** may take the form of switches that may be controlled remotely by a computer system in cell control system **146**.

In some illustrative examples, a cell in plurality of cells **106** may be part of another cell in plurality of cells **106**. A cell that is part of another cell in plurality of cells **106** distributes electrical energy **102** to an area located within the area corresponding to the other cell. A cell within another cell may be referred to as a "sub-cell" in these illustrative examples. A cell in plurality of cells **106** may have any number of sub-cells.

With reference now to FIG. **2**, an illustration of a power distribution grid is depicted in accordance with an illustrative embodiment. Power distribution grid **200** is an example of one implementation for power distribution grid **100** in FIG. **1**. Power distribution grid **200** is configured to deliver power to loads within region **201**. In this illustrative example, region **201** is a region in a city.

As depicted, power distribution grid **200** comprises plurality of cells **202**. Plurality of cells **202** includes cell **204**, cell **206**, cell **208**, cell **210**, cell **212**, cell **214**, cell **216**, cell **218**, and cell **220**. Each of these cells is configured to deliver power to a corresponding area in region **201**. For example, cell **204**, cell **206**, cell **208**, cell **210**, cell **212**, cell **214**, cell **216**, cell **218**, and cell **220** are configured to deliver power to loads within area **205**, area **207**, area **209**, area **211**, area **213**, area **215**, area **217**, area **219**, and area **221**, respectively.

Plurality of cells **202** may cooperatively control the distribution of power within region **201**. However, in this illustrative example, each cell in plurality of cells **202** also may be configured to be independent of the other cells in plurality of cells **202**. For example, a cell in plurality of cells **202**, such as cell **204**, may be configured to monitor the distribution of power within cell **204** independently of the other cells in plurality of cells **202**. Further, this cell may be configured to control the distribution of power within that cell independently of the other cells in plurality of cells **202**.

Further, as depicted, in some cases, a cell may have a sub-cell. The sub-cell is configured to deliver power to a sub-area within the area corresponding to the cell to which the sub-cell belongs. For example, cell **206** has sub-cell **222**, cell **210** has sub-cell **224**, and cell **214** has sub-cell **226**. Sub-cell **222**, sub-cell **224**, and sub-cell **226** are configured to deliver power to sub-area **223**, sub-area **225**, and sub-area **227**, respectively.

In this illustrative example, a sub-cell may monitor and control the distribution of power within the sub-cell independently of the cell to which the sub-cell belongs. For example, sub-cell **222** may monitor and control the distribution of power within sub-cell **222** independently of cell **206**.

As depicted, plurality of cells **202** are connected to each other by entry nodes. In particular, a cell may share one or more entry nodes with one or more other cells in plurality of cells **202**. For example, cell **204** and cell **206** share entry node **228**. Cell **204** and cell **210** share entry node **229**. Cell **206** shares entry node **230** with cell **208** and entry node **232** with cell **212**. Cell **208** shares entry node **234** with cell **214**.

Further, cell **210** shares entry node **236** with cell **212** and entry node **238** with cell **216**. Cell **212** shares entry node **240** with cell **214** and entry node **242** with cell **218**. Additionally, cell **214** shares entry node **244** with cell **220**. Cell **216** shares entry node **246** with cell **218**. Cell **218** shares entry node **248** with cell **220**.

With reference now to FIG. **3**, an illustration of a cell is depicted in accordance with an illustrative embodiment. Cell **300** is an example of one implementation for a cell in a power distribution grid, such as, for example, cell **110** in power distribution grid **100** in FIG. **1**. Further, cell **300** may be used to implement any one of plurality of cells **202** in power distribution grid **200** in FIG. **2**. Cell **300** is configured to distribute electrical energy to area **301**.

In this illustrative example, cell **300** comprises electrical lines **302**, nodes **304**, monitoring devices **306**, and control devices **308**. Monitoring devices **306** form cell monitoring system **307** for cell **300**. Cell monitoring system **307** is an example of one implementation for cell monitoring system **133** in FIG. **1**. Monitoring devices **306** in cell monitoring system **307** are examples of one implementation for monitoring devices in plurality of monitoring devices **128** in FIG. **1**. In this illustrative example, monitoring devices **306** take the form of power meters.

Further, control devices **308** form cell control system **309** for cell **300**. Cell control system **309** is an example of one implementation for cell control system **146** in FIG. **1**. Control devices **308** in cell control system **309** are examples of one implementation for control devices in plurality of control devices **138** in FIG. **1**. Control devices **308** take the form of switches in this illustrative example.

As depicted, nodes **304** include plurality of entry nodes **310**. Electrical energy may flow into cell **300** through one or more of plurality of entry nodes **310** into one or more of plurality of sectors **312** in cell **300**. As used herein, a "sector" is a portion of a cell and may comprise any number of electrical lines and nodes. A cell, such as cell **300**, may have any number of sectors. Further, a cell may have any number of subsectors. A subsector may be a sector within another sector.

For example, plurality of entry nodes **310** includes entry node **314**, entry node **316**, entry node **318**, and entry node **320**. Plurality of sectors **312** includes first sector **322**, second sector **324**, third sector **326**, and fourth sector **328**. Electrical energy may flow into first sector **322**, second sector **324**, third sector **326**, and fourth sector **328** of cell **300** through entry node **314**, entry node **316**, entry node **318**, and entry node **320**, respectively.

In this illustrative example, control devices **308** include entry control devices **311**. Entry control devices **311** control whether electrical energy flows from an entry node in plurality of entry nodes **310** to a sector in plurality of sectors **312**. As depicted, entry control devices **311** include entry control device **321**, entry control device **323**, entry control device **325**, and entry control device **327**.

In particular, entry control device **321**, entry control device **323**, entry control device **325**, and entry control device **327** control whether electrical energy is allowed to flow from entry node **314**, entry node **316**, entry node **318**, and entry node **320**, respectively, into first sector **322**, second sector **324**, third sector **326**, and fourth sector **328** of cell **300**, respectively.

Electrical energy that flows into plurality of sectors **312** may be delivered to set of loads **315** electrically connected to cell **300**. As depicted, set of loads **315** include load **330**, load **332**, load **334**, and load **336**. Electrical energy that flows into first sector **322**, second sector **324**, third sector **326**, and fourth sector **328** of cell **300** is delivered to load **330**, load **332**, load **334**, and load **336**, respectively.

In this illustrative example, cell control system **309** controls control devices **308** such that electrical energy may flow into a sector in plurality of sectors **312** through only one of plurality of entry nodes **310**. However, each sector in plurality of sectors **312** may be configured to be electrically connected to each other by electrical lines **302**.

Electrical lines **302** are configured to allow any sector in plurality of sectors **312** to have the capability to receive electrical energy that enters cell **300** from any one of plurality of entry nodes **310**. Cell control system **309** determines which of electrical lines **302** may be used to deliver electrical energy to each load in set of loads **315**.

In one illustrative example, cell control system **309** may determine that an undesired event has occurred at location **340** in area **301**. This identification may be made based on data received from cell monitoring system **307**. In particular, this identification may be made using data received from monitoring device **342** in monitoring devices **306**.

Consequently, cell control system **309** uses control devices **308** to isolate location **340**. In other words, cell control system **309** uses control devices **308** to reduce the flow of electrical energy into and out of location **340**. The flow of electrical energy into and out of location **340** may be reduced to about zero. When the flow of electrical energy into location **340** is reduced to about zero, load **332** may be unable to receive electrical energy from second sector **324**. As a result, cell control system **309** may reroute the flow of electrical energy through electrical lines **302** using control devices **308** such that load **332** may receive electrical energy supplied from one of first sector **322**, third sector **326**, and fourth sector **328**.

In some illustrative examples, cell control system **309** may be configured to change load patterns within cell **300**. For example, cell control system **309** may change the amount of electrical energy delivered to each load in set of loads **315**. Further, in some cases, cell control system **309** may be configured to resolve undesired events that are detected within cell **300** to maintain a desired power quality and/or desired power stability without requiring a maintenance crew to be present.

With reference now to FIG. **4**, an illustration of a sector in a cell is depicted in accordance with an illustrative embodiment. In this illustrative example, second sector **324** from FIG. **3** is described in greater detail. As depicted, entry control device **323** controls the flow of electrical energy from entry node **316** into second sector **324** through electrical line **400**.

Entry control device **323** may take the form of switch **401** in this illustrative example. Switch **401** is configured to control the flow of electrical energy through electrical line **400** at location **403**. For example, switch **401** may electrically disconnect node **402** in second sector **324** from entry node **316** at location **403** along electrical line **400** to reduce and/or prevent the flow of electrical energy from entry node **316** into second sector **324**. Further, switch **401** may electrically connect node **402** in second sector **324** to entry node **316** at location **403** along electrical line **400** to allow electrical energy to flow from entry node **316** into second sector **324**. In this illustrative example, node **402** may be an entry node for second sector **324**.

As depicted, electrical energy that flows into second sector **324** through node **402** may flow into electrical line **404**, electrical line **406**, and electrical line **408**. Monitoring device **410** in second sector **324** is configured to monitor a set of parameters along electrical line **404**. Monitoring device **412** in second sector **324** is configured to monitor a set of parameters along electrical line **406**. Monitoring device **414** in second sector **324** is configured to monitor a set of parameters along electrical line **408**. The sets of parameters monitored by monitoring device **410**, monitoring device **412**, and monitoring device **414** may be, for example, set of parameters **132** in FIG. **1**.

Electrical energy may flow through electrical line **406** and into subsector **416** in second sector **324** of cell **300**. Electrical energy may enter subsector **416** through node **418**. Control device **420** in subsector **416** controls the flow of electrical energy from node **418** to transformer **422**. For example, control device **420** may take the form of switch **421**.

Transformer **422** is configured to convert this electrical energy from high voltage electrical energy to low voltage electrical energy. The low voltage electrical energy is then carried from transformer **422** to load **332** through electrical line **426**. Monitoring device **424** monitors the flow of electrical energy from transformer **422** to load **332** through electrical line **426**.

The illustrations of cell **300** in FIG. **3** and second sector **324** in FIG. **4** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. The different components shown in FIGS. **3-4** may be combined with components in FIG. **1**, used with components in FIG. **1**, or a combination of the two. Additionally, some of the components in FIGS. **3-4** may be illustrative examples of how components shown in block form in FIG. **3** can be implemented as physical structures.

For example, in some illustrative examples, electrical lines may be added to and/or removed from cell **300**, second sector **324**, and/or any one of plurality of sectors **312** in FIG. **3**. Further, one or more additional loads may be electrically connected to a sector in plurality of sectors **312**. In some cases, one or more of set of loads **315** may be electrically disconnected from a sector in plurality of sectors **312**.

In still other illustrative examples, transformers, control devices, monitoring devices, circuit breakers, and/or other suitable types of components may be added to and/or removed from cell **300**. In this manner, a cell, such as cell **300**, may be implemented in a number of different ways. Further, cell **300** may change over time as different components are added to and/or removed from cell **300**. For example, cell **300** may be modified over time to change the distribution of electrical energy to area **301** by cell **300**. In particular, the loads electrically connected to cell **300** and/or the portions within area **301** supplied with electrical energy by cell **300** may grow over time.

With reference now to FIG. **5**, an illustration of a process for managing a distribution of electrical energy by a power distribution grid in the form of a flowchart is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **5** may be implemented using power distribution grid **100** in FIG. **1** and, in particular, power management system **120** in FIG. **1**.

The process begins by monitoring a distribution of electrical energy in a power distribution grid at a plurality of monitoring locations in the power distribution grid (operation **500**). The power distribution grid comprises a plurality of cells configured to distribute the electrical energy to a plurality of areas. In these illustrative examples, each cell in the plurality of cells has a plurality of entry nodes configured to allow the electrical energy to flow into the cell.

Operation **500** may be performed using a monitoring system, such as, for example, monitoring system **122** in FIG. **1**. The monitoring system may generate data for a set of parameters being monitored at each of the plurality of monitoring locations in the power distribution grid. This data may provide information about the health and status of the power distribution grid with respect to the plurality of monitoring locations.

The process then controls a flow of the electrical energy in the plurality of cells in the power distribution grid at a plurality of control locations in the power distribution grid (operation **502**), with the process terminating thereafter. In operation **502**, the flow of the electrical energy in a particular cell in the plurality of cells may be controlled independently of the flow of the electrical energy in other cells in the plurality of cells.

Operation **502** may be performed using a control system, such as, for example, control system **124** in FIG. **1**. The control system may control the flow of electrical energy in the plurality of cells in operation **502** using the data generated during operation **500**. Operation **500** and operation **502** may be performed continuously such that the health and status of the power distribution grid may be managed in substantially real-time. In operation **502**, controlling the flow of electrical energy in the plurality of cells may be performed using data generated during operation **500**.

With reference now to FIG. **6**, an illustration of a process for monitoring the distribution of electrical energy by a cell in a power distribution grid in the form of a flowchart is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **6** may be used to implement operation **500** in FIG. **5**. Further, this process may be used to monitor a particular cell in a plurality of cells in the power distribution grid.

This process may be implemented using monitoring system **122** in power management system **120** in FIG. **1**. In particular, this process may be implemented using one of plurality of cell monitoring systems **131**, such as, for example, cell monitoring system **133** in FIG. **1**.

The process begins by monitoring a set of parameters at each of a set of monitoring locations in a cell using a cell monitoring system (operation **600**). The set of parameters may include, for example, without limitation, at least one of voltage, current, electrical power, electrical energy, temperature, impedance, capacity, thermal conductivity, and other suitable types of parameters.

The process generates data using the cell monitoring system, while monitoring the set of parameters (operation **602**). The data generated in operation **602** may include, for example, without limitation, at least one of values for the set of parameters, a report, a log, a spreadsheet, an alert, and other suitable information.

Thereafter, the process sends the data to a cell control system for processing (operation **604**), with the process then returning to operation **600** as described above. Although this process has been described as a sequence of steps, operation **600**, operation **602**, and operation **604** may be performed continuously, in substantially real-time, and/or simultaneously in these illustrative examples.

With reference now to FIG. **7**, an illustration of a process for controlling a flow of electrical energy in a cell in a power distribution grid in the form of a flowchart is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **7** may be used to implement operation **500** in FIG. **5**. Further, this process may be used to control the flow of electrical energy within a particular cell in a plurality of cells in the power distribution grid.

This process may be implemented using control system **124** in power management system **120** in FIG. **1**. In particular, this process may be implemented using one of plurality of cell control systems **144**, such as, for example, cell control system **146** in FIG. **1**.

The process begins by receiving data generated by a cell monitoring system at a cell control system (operation **700**). In operation **700**, the data received may be, for example, the data generated in operation **502** in FIG. **5**. In some cases, in operation **700**, the cell control system may receive additional information from a main control system and/or other suitable information. In these illustrative examples, operation **700** may be an operation that is performed continuously.

The process then determines whether an undesired event has occurred based on the data (operation **702**). In some cases, the cell control system may use other information in addition to the data generated by the cell monitoring system to determine whether an undesired event has occurred. For example, the cell control system may use information received from a main control system, a policy, safety requirements, regulations, and/or other suitable information to make the determination in operation **702**.

If the undesired event has not occurred, the process returns to operation **700** as described above. Otherwise, if an undesired event has occurred, the process identifies a number of changes to be made to the flow of electrical energy within the cell to resolve the undesired event (operation **704**).

Thereafter, the process sends a set of commands to a set of control devices in the cell control system to perform the number of changes identified (operation **706**), with the process then returning to operation **700** as described above. The set of control devices may be, for example, a set of switches.

In one illustrative example, the set of control devices may be controlled by the set of commands to isolate a location in which the undesired event has occurred, reroute the delivery of electrical energy to one or more loads electrically connected to the cell, and/or change the flow of electrical energy within the cell in some other suitable manner. In this manner, the cell may be configured to maintain a continuous supply of electrical energy to loads electrically connected to the cell even when undesired events occur within the cell.

Using the processes described in FIG. **5**, FIG. **6**, and FIG. **7**, the health and status of a power distribution grid may be monitored in substantially real-time. Further, undesired events that may occur in a power distribution grid may be resolved with a desired expediency and efficiency. Still further, cells may be monitored and controlled independently of other cells in a power distribution grid. In this manner, the time and/or effort required to identify, investigate, and/or resolve an undesired event may be reduced.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step. For example, one or more of the blocks may be implemented as program code, in hardware, or a combination of the program code and hardware. When implemented in hardware, the hardware may, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Turning now to FIG. **8**, an illustration of a data processing system is depicted in accordance with an illustrative embodiment. Data processing system **800** may be used to implement a processor unit in a control system, such as control system **124** and/or a processor unit in a monitoring system, such as monitoring system **122** in FIG. **1**. In particular, data processing system **800** may be used to implement a processor unit in a control device, such as one of plurality of control devices **138** and/or a processor unit in a monitoring device, such as one of plurality of monitoring devices **128** in FIG. **1**.

In this illustrative example, data processing system **800** includes communications framework **802**, which provides communications between processor unit **804**, memory **806**, persistent storage **808**, communications unit **810**, input/output (I/O) unit **812**, and display **814**. In this example, communications framework **802** may take the form of a bus system.

Processor unit **804** serves to execute instructions for software that may be loaded into memory **806**. Processor unit **804** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular implementation.

Memory **806** and persistent storage **808** are examples of storage devices **816**. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, data, program code in functional form, and/or other suitable information either on a temporary basis and/or a permanent basis. Storage devices **816** may also be referred to as computer readable storage devices in these illustrative examples. Memory **806**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **808** may take various forms, depending on the particular implementation.

For example, persistent storage **808** may contain one or more components or devices. For example, persistent storage **808** may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **808** also may be removable. For example, a removable hard drive may be used for persistent storage **808**.

Communications unit **810**, in these illustrative examples, provides for communications with other data processing systems or devices. In these illustrative examples, communications unit **810** is a network interface card.

Input/output unit **812** allows for input and output of data with other devices that may be connected to data processing system **800**. For example, input/output unit **812** may provide a connection for user input through a keyboard, a mouse, and/or some other suitable input device. Further, input/output unit **812** may send output to a printer. Display **814** provides a mechanism to display information to a user.

Instructions for the operating system, applications, and/or programs may be located in storage devices **816**, which are in communication with processor unit **804** through communications framework **802**. The processes of the different embodiments may be performed by processor unit **804** using computer-implemented instructions, which may be located in a memory, such as memory **806**.

These instructions are referred to as program code, computer usable program code, or computer readable program code that may be read and executed by a processor in processor unit **804**. The program code in the different embodiments may be embodied on different physical or computer readable storage media, such as memory **806** or persistent storage **808**.

Program code **818** is located in a functional form on computer readable media **820** that is selectively removable and may be loaded onto or transferred to data processing system **800** for execution by processor unit **804**. Program code **818** and computer readable media **820** form computer program product **822** in these illustrative examples. In one example, computer readable media **820** may be computer readable storage media **824** or computer readable signal media **826**.

In these illustrative examples, computer readable storage media **824** is a physical or tangible storage device used to store program code **818** rather than a medium that propagates or transmits program code **818**. Alternatively, program code **818** may be transferred to data processing system **800** using computer readable signal media **826**. Computer readable signal media **826** may be, for example, a propagated data signal containing program code **818**.

For example, computer readable signal media **826** may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other suitable type of communications link.

The different components illustrated for data processing system **800** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a data processing system including components in addition to and/or in place of those illustrated for data processing system **800**. Other components shown in FIG. **8** can be varied from the illustrative examples shown. The different embodiments may be implemented using any hardware device or system capable of running program code **818**.

Thus, the different illustrative embodiments provide a method and apparatus for managing a power distribution grid. In one illustrative embodiment, a power distribution grid comprises a plurality of cells configured to be electrically connected to each other and a power management system. A cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell. The cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell. The power management system is configured to manage a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells.

The description of the different illustrative embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other illustrative embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A power distribution grid comprising:

a plurality of cells configured to be electrically connected to each other, wherein a cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell and wherein the cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell; and

a power management system configured to manage a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells;

wherein the plurality of cells is formed by electrical lines and nodes in the power distribution grid and wherein the cell in the plurality of cells comprises:

a plurality of sectors configured to be electrically connected to each other such that a sector in the plurality of sectors is capable of receiving the electrical energy from more than one entry node in the plurality of entry nodes, wherein the sector is configured to deliver the electrical energy to a load electrically connected to the sector;

wherein each sector of the plurality sectors comprises an entry node for the sector and a load in the sector;

wherein a first entry node of the plurality of entry nodes is connected to a first smart switch associated with a first sector of the plurality of sectors;

wherein a first node in the first sector is connected to

the smart switch,

a first node of a second sector,

a second node of the first sector, and

a first node of a third sector;

wherein the connection between the first node of the first sector and the first node of the second sector includes

a first power monitor in the first sector, and

a first power monitor in the second sector;

wherein the second node of the first sector is connected to

the first node of the first sector,

a smart switch of the first sector, and

a second smart switch associated with the first sector; and

wherein the second smart switch associated with the first sector is connected to

a node of the cell that is connected to

the second smart switch associated with the first sector,

a second smart switch associated with the second sector,

a second smart switch associated with the third sector, and

a second smart switch associated with a fourth sector.

2. The power distribution grid of claim **1**, wherein the power management system comprises:

a monitoring system configured to monitor the distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to the other areas by the other cells in the plurality of cells; and

a control system configured to control the distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to the other areas by the other cells in the plurality of cells.

3. The power distribution grid of claim **2**, wherein the monitoring system comprises:

a plurality of monitoring devices configured to monitor a plurality of monitoring locations in the power distribution grid, wherein a monitoring device in the plurality of monitoring devices is configured to monitor a set of parameters at a corresponding monitoring location in the plurality of monitoring locations.

4. The power distribution grid of claim **3**, wherein the plurality of monitoring devices forms a plurality of cell monitoring systems in which a cell monitoring system in the plurality of cell monitoring systems is configured to monitor the distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to the other areas by the other cells in the plurality of cells.

5. The power distribution grid of claim **3**, wherein the set of parameters includes at least one of voltage, current, electrical energy, electrical power, capacity, thermal conductivity, impedance, and temperature.

6. The power distribution grid of claim **3**, wherein the monitoring device in the plurality of monitoring devices comprises at least one of a voltmeter, an ammeter, an ohmmeter, a power meter, a temperature sensor, a processor unit, and a communications unit.

7. The power distribution grid of claim **2**, wherein the control system comprises:

a plurality of control devices configured to control a flow of the electrical energy at a plurality of control locations in the power distribution grid, wherein a control device in the plurality of control devices is configured to control the flow of the electrical energy at a corresponding control location in the plurality of control locations.

8. The power distribution grid of claim **7**, wherein the plurality of control devices forms a plurality of cell control systems in which a cell control system in the plurality of cell control systems is configured to control the distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to the other areas by the other cells in the plurality of cells.

9. The power distribution grid of claim **7**, wherein the control device is configured to control the flow of the electrical energy at the corresponding control location in the plurality of control locations by at least one of reducing an amount of the electrical energy that can flow through an electrical line at the corresponding control location, decreasing an impedance of the electrical line at the corresponding control location, increasing the impedance of the electrical line at the corresponding control location, and preventing the flow of the electrical energy through the electrical line at the corresponding control location.

10. The power distribution grid of claim **7**, wherein the control device comprises at least one of a switch, a switchgear, a flexible alternating current transmissions device, a fuse, a circuit breaker, a smart switch, an electronic filter, a phase shifter, a transformer, an adapter, a sensor, a processor unit, and a communications unit.

11. The power distribution grid of claim **7**, wherein the control system further comprises:

a main control system configured to control the distribution of the electrical energy by the plurality of cells in the power distribution grid, wherein the main control system is configured to be in communication with the monitoring system and the plurality of control devices.

12. The power distribution grid of claim **2** further comprising:

a communications network configured to allow communications between the monitoring system and the control system through at least one of a number of wireless communications links, a number of wired communications links, a number of electrical lines in the power distribution grid, and a number of optical communications links.

13. The power distribution grid of claim **1**,

wherein the area corresponding to the cell is one of a plurality of areas in a region that are distinct and do not overlap within the region;

wherein the region is one of a geographical region, a city, an area in a city, a town, and a neighborhood; and

wherein an entry node of the plurality of entry nodes electrically connects the cell to

14. The power distribution grid of claim **1**,

wherein the plurality of entry nodes includes four entry nodes;

wherein the plurality of sectors includes four sectors;

wherein the cell includes four loads, one in each of the four sectors;

wherein each of the four entry nodes controls a flow of power into one of the four sectors;

wherein the connection between the first node of the first sector and the second node of the first sector includes a second power monitor in the first sector;

wherein the connection between the first node of the first sector and the first node of the third sector includes

a third power monitor in the first sector and

a first power monitor in the third sector;

wherein the smart switch of the first sector is connected to the second node of the first sector and

a transformer of the first sector; another cell of the plurality of cells.

wherein the transformer of the first sector is connected to the smart switch of the first sector and

a first load of the four loads that is in the first sector;

wherein the connection between the transformer of the first sector and the first load includes a fourth power monitor in the first sector; and

wherein the second smart switch associated with the first sector is connected to the second node of the first sector.

15. A power distribution grid comprising:

a plurality of cells configured to be electrically connected to each other, wherein a cell in the plurality of cells is configured to distribute electrical energy to an area corresponding to the cell, wherein the cell has a plurality of entry nodes configured to allow the electrical energy to flow into the cell, and wherein the cell comprises:

a plurality of sectors configured to be electrically connected to each other, wherein a sector in the plurality of sectors is configured to deliver the electrical energy to a load electrically connected to the sector and wherein the sector is configured to have a capability to receive the electrical energy from more than one entry node in the plurality of entry nodes;

a monitoring system configured to monitor a distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to other areas by other cells in the plurality of cells; and

a control system configured to control the distribution of the electrical energy to the area by the cell independently of the distribution of the electrical energy to the other areas by the other cells in the plurality of cells;

wherein each sector of the plurality sectors comprises an entry node for the sector and a load in the sector;

wherein a first entry node of the plurality of entry nodes is connected to a first smart switch associated with a first sector of the plurality of sectors;

wherein a first node in the first sector is connected to

the smart switch,

a first node of a second sector,

a second node of the first sector, and

a first node of a third sector;

wherein the connection between the first node of the first sector and the first node of the second sector includes

a first power monitor in the first sector, and

a first power monitor in the second sector;

wherein the second node of the first sector is connected to

the first node of the first sector,

a smart switch of the first sector, and

a second smart switch associated with the first sector; and

wherein the second smart switch associated with the first sector is connected to

a node of the cell that is connected to

the second smart switch associated with the first sector,

a second smart switch associated with the second sector,

a second smart switch associated with the third sector, and

a second smart switch associated with a fourth sector.

16. A method for managing a power distribution grid, the method comprising:

monitoring a distribution of electrical energy in the power distribution grid at a plurality of monitoring locations, wherein the power distribution grid comprises a plurality of cells configured to distribute the electrical energy to a plurality of areas in which a cell in the plurality of cells has a plurality of entry nodes configured to allow the electrical energy to flow into the cell; and

controlling a flow of the electrical energy in the plurality of cells in the power distribution grid at a plurality of control locations in which the flow of the electrical energy in the cell in the plurality of cells is controlled independently of the flow of the electrical energy in other cells in the plurality of cells;

wherein the step of controlling the flow of the electrical energy in the plurality of cells in the power distribution grid at the plurality of control locations comprises:

controlling a delivery of the electrical energy to a load electrically connected to a sector in a plurality of sectors in the cell, wherein the plurality of sectors is configured to be electrically connected to each other such that the sector is capable of receiving the electrical energy from more than one entry node in the plurality of entry nodes for the cell;

wherein each sector of the plurality sectors comprises an entry node for the sector and a load in the sector;

wherein a first entry node of the plurality of entry nodes is connected to a first smart switch associated with a first sector of the plurality of sectors;

wherein a first node in the first sector is connected to

the smart switch,

a first node of a second sector,

a second node of the first sector, and

a first node of a third sector;

wherein the connection between the first node of the first sector and the first node of the second sector includes

a first power monitor in the first sector, and

a first power monitor in the second sector;

wherein the second node of the first sector is connected to

the first node of the first sector,

a smart switch of the first sector, and

a second smart switch associated with the first sector; and

wherein the second smart switch associated with the first sector is connected to

a node of the cell that is connected to

the second smart switch associated with the first sector,

a second smart switch associated with the second sector,

a second smart switch associated with the third sector, and

a second smart switch associated with a fourth sector.

17. The method of claim **16**, wherein the step of monitoring the distribution of the electrical energy in the power distribution grid at the plurality of monitoring locations comprises:

monitoring the distribution of the electrical energy in the power distribution grid using a monitoring system comprising a plurality of monitoring devices configured to monitor a set of parameters at the plurality of monitoring locations in the power distribution grid, wherein the plurality of monitoring devices forms a plurality of cell monitoring systems in which a cell monitoring system in the plurality of cell monitoring systems is configured to monitor a corresponding cell in the plurality of cells.

18. The method of claim **17**, wherein the step of monitoring the distribution of the electrical energy in the power distribution grid using the monitoring system comprising the plurality of monitoring devices configured to monitor the set of parameters at the plurality of monitoring locations in the power distribution grid comprises:

monitoring the distribution of the electrical energy in the power distribution grid using the monitoring system comprising the plurality of monitoring devices configured to monitor the set of parameters at the plurality of monitoring locations in the power distribution grid in which the set of parameters includes at least one of voltage, current, electrical energy, electrical power, capacity, thermal conductivity, impedance, and temperature and in which a monitoring device in the plurality of monitoring devices comprises at least one of a voltmeter, an ammeter, an ohmmeter, a power meter, a temperature sensor, a processor unit, and a communications unit.

19. The method of claim **16**, wherein the step of controlling the flow of the electrical energy in the plurality of cells in the power distribution grid at the plurality of control locations comprises:

controlling the flow of the electrical energy in the plurality of cells in the power distribution grid using a control system comprising a plurality of control devices configured to control the flow of the electrical energy at the plurality of control locations in the power distribution grid, wherein the plurality of control devices forms a plurality of cell control systems in which a cell control system in the plurality of cell control systems is configured to control the flow of the electrical energy in a corresponding cell in the plurality of cells.

20. The method of claim **19**, wherein the step of controlling the flow of the electrical energy in the plurality of cells in the power distribution grid using the control system comprising the plurality of control devices configured to control the flow of the electrical energy at the plurality of control locations in the power distribution grid comprises:

controlling the flow of the electrical energy in the plurality of cells in the power distribution grid using the control system comprising the plurality of control devices configured to control the flow of the electrical energy at the plurality of control locations in the power distribution grid, wherein a control device in the plurality of control devices comprises at least one of a switch, a switchgear, a flexible alternating current transmissions (FACTs) device, a fuse, a circuit breaker, a smart switch, an electronic filter, a phase shifter, a transformer, an adapter, a sensor, a processor unit, and a communications unit.

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